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The SNS Low Level RF Development and Production Plan

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THE SNS LOW LEVEL RF DEVELOPMENT AND PRODUCTION PLAN

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1.1 INTRODUCTION

The development and production of the RFQ, Linac and HEBT Low Level RF (LLRF) control system was reviewed in September 2002, by a subset of the Accelerator Systems Advisory Committee and a group of experts having knowledge of and experience with similar systems and technologies. The review committee concluded that at this stage of the project, with increasing schedule pressure to meet upcoming commissioning dates, a more centrally organized effort was necessary [1]. The committee recommended that:

1. The oversight and responsibility should move to Oak Ridge National Laboratory (ORNL);
2. All of the relevant Spallation Neutron Source (SNS) partner lab resources should be brought together;
3. The system requirements should be reviewed;
4. Additional resources should be brought in as necessary at Los Alamos National Laboratory (LANL) and Lawrence Berkeley National Laboratory (LBNL); and
5. Outsourcing to industry should be considered.

A new SNS LLRF team was created immediately after the review to address the challenges of fulfilling the LLRF system requirements. The main goal of the team is to develop, integrate, manufacture, deploy and operate 94 complete LLRF control systems plus spares over the next 2 years. LANL, LBNL and ORNL will be significantly involved in all phases through successful completion. The team will draw upon resources within the SNS collaboration and will augment its resources as necessary to fulfill its mission. A key to the implementation plan is a graded approach to meet all system requirements as outlined in the newly issued system requirements document [2]. This will enable the LLRF control system to serve the needs of the SNS accelerator, as installation moves from the Front End to the HEBT, and as the project moves from conditioning to commissioning and finally full power operation.

1.2 OVERALL APPROACH AND GENERAL ORGANIZATION

Arrangements and authorities in the existing Interlab Memoranda of Understanding (MOA), which forms the basis of the SNS collaboration, covers this work since it is part of the present SNS baseline. The new team structure and implementation plan follows the successful model used by the SNS Accelerator Diagnostics group and the Global Controls group. While various teams, spread across the collaboration, work on specific subsystems, integration responsibility lies with the Accelerator Systems Division (ASD) at ORNL. Similar to Diagnostics, the LLRF team has its own Advisory Board that is very much integrated in the determination of the technical solutions that will be implemented and in the decision making process itself. This board has technical as well as management expertise and is reviewing engineering practices, progress, and consistency of documentation that comes with the development. The chair of the Advisory Board will report to the ASD division office on all these items on a monthly basis to provide for early management involvement by the division if necessary.

A chart illustrating the core responsibility of each individual as well as the Laboratories' scope of work is given in Figure 1. The chart also indicates the type of system configuration control that is being used: common development tools between the different teams and a common set of process variables that will make the actual hardware indistinguishable from the Operations points of view. The CVS repository already in regular use at ORNL will be used for software version control. The chart also represents the state of the development today, with LBNL having an operational smaller scale system, and the team developing the fully-grown system with a widened range of capabilities over the course of fiscal year 2003.

The team will use the existing assets [3], such as the working LLRF control system in the MEBT Rebuncher (LBNL) and the Mature High Power Protect Module (LANL), to meet near term testing and

commissioning requirements, and will build upon these assets to develop the final system that will begin deployment in February 2004 for the CCL and SCL. The team will quickly define the final system configuration with recently revised requirements, with the help of LLRF experts, within the existing constraints of schedule and budget.

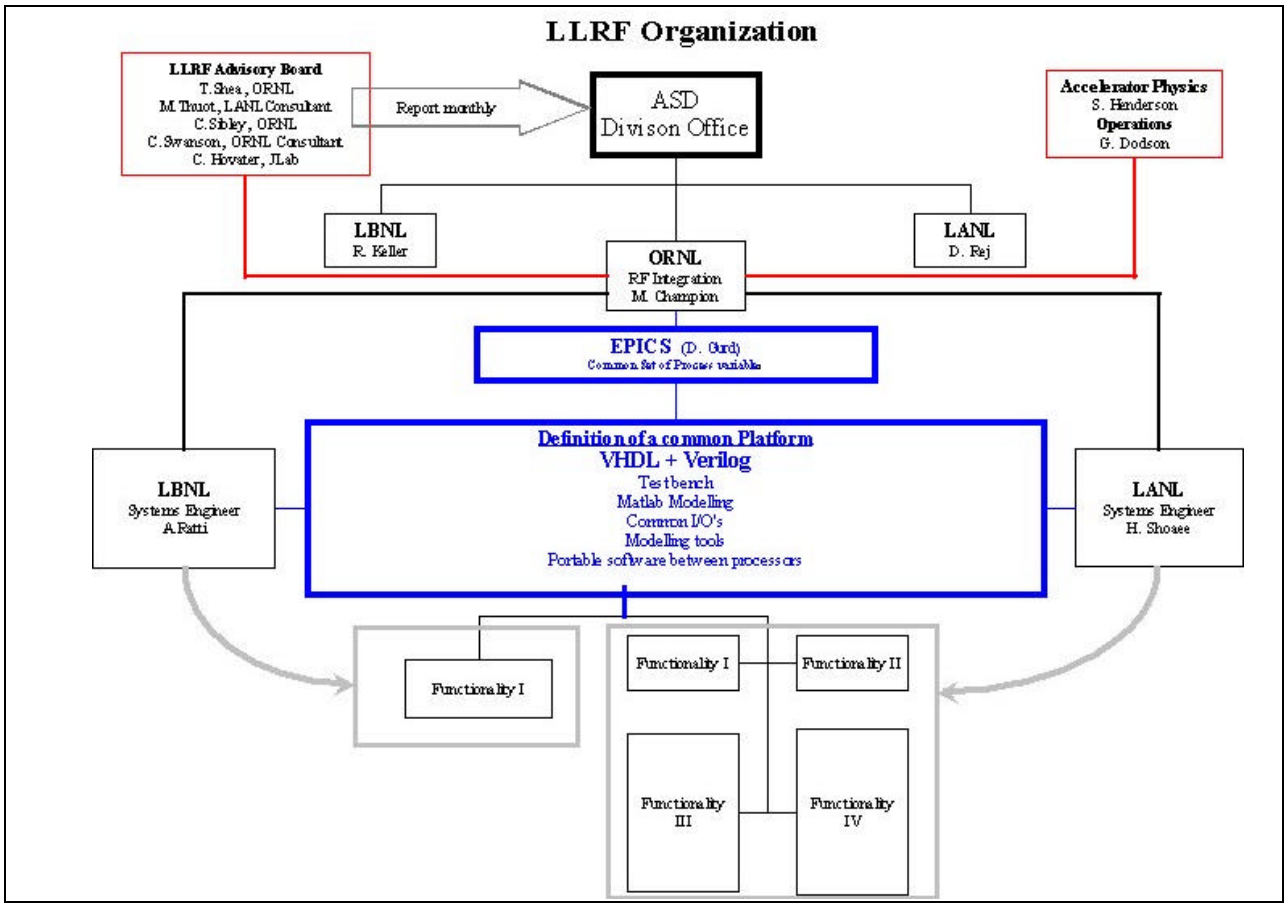

Figure 1. The LLRF Organization Chart

1.3 LLRF TEAM

The functional organization of the team is presented in Table 1. Some of the team members will be 100% committed to this effort; others will support the effort on a part-time basis. The team membership will be changed as necessary to meet the needs of the program.

Mark Champion, ORNL Team Leader, Project Integration	
Alex Ratti, LBNL Team Leader	
Hamid Shoaee, LANL Team Leader	
Engineering	Engineering & Installation Support
Larry Doolittle, LBNL	Mark Crofford*, LANL
Marco Monroy, LBNL	Taylor Davidson, ORNL
Hengjie Ma, ORNL	Brian Gross, ORNL
Chip Piller, ORNL	Mark Regis, LBNL
Mark Prokop, LANL	Other Technicians as needed
Amy Regan, LANL	
Vincent Riot, LBNL	System Modeling
Matt Stettler, LANL	Stefano DeSantis, LBNL
Dave Thomson, LANL	Sang-ho Kim, ORNL
	Sung-il Kwon, LANL
Auxiliary Systems	
Eric Bjorklund*, LANL	EPICS Support
Herb Strong, ORNL	Pam Gurd, ORNL
Dave Warren, LANL	Kay Kasemir, LANL
Ernest Williams, ORNL	Carl Lionberger*, LBNL
*On change of station at ORNL	

Table 1. The LLRF Team Members

1.4 NEAR-TERM PLAN

- The LANL group will halt its efforts to get the Field and Resonance Control Module (FRCM) running. This step is being taken because: 1) there is no credible time estimate for completing the FRCM; 2) the team has already decided the ultimate hardware design will be substantially different from the existing FRCM; 3) the firmware for the ultimate design will be written in a higher level language (VHDL/Verilog) that is more amenable to complete system simulation; 4) there is a proven alternative platform that can be used for near-term algorithm development.
- The LBNL group will provide the common development platform for all three labs. This will integrate our efforts, provide a working platform for algorithm development, enable us to standardize on VHDL/Verilog, and make possible a meaningful test of a prototype LLRF control system with a cryomodule at JLab in January 2003.
- The LBNL control system and the LANL High Power Protect Module (HPM) will be used together for RFQ and DTL commissioning.
- An Interface Control Document will be written by November 30, 2002, to accompany the new LLRF system requirements document. It will specify hardware and software interconnects.

1.5 LONG -TERM PLAN

The team has already begun the development of the redesigned system. A kickoff and brainstorming session was held October 25 at LBNL. Some issues that were addressed include:

- Three possible architectures:
  - VME/VXI
  - PCI
  - Local NanoEngine (evolution of LBNL hardware)
- Identify the principle system designer
- Define the analog front end (LANL daughter card, LBNL front end, Bergoz BPM front end)
- Define the digital board

At this time the conceptual design for the final Field Control Module (FCM) calls for a relatively simple digital board that will include Analog to Digital Converters (ADC), a Field Programmable Gate Array (FPGA), and Digital to Analog Converters (DAC). The analog 50 MHz inputs and output will be handled by one or two daughter cards that attach directly to the digital board. The FCM will be packaged as a VXI bus device.

The conceptual design will be completed in late 2002. The detailed design will be completed in early 2003 and a prototype system will be completed in March 2003. This gives us a window of opportunity to test the system with beam on DTL1 in June-July 2003. Production begins thereafter with the first systems due in February 2004 to support CCL and SCL commissioning. The DTL and RFQ LLRF control systems may be retrofitted so the entire linac has a common LLRF control system.

1.6 TASK MANAGEMENT

The breakdown of the main tasks and responsibilities as they have been split among the LLRF team is described as follows:

1.6.1 System Simulations (Matlab)

- Will build on LANL models and utilize at partner labs
- Will validate models through commissioning experience
- Will test the integration with FPGA programming
- Uses CVS repository system

1.6.2 FPGA Programming (VHDL/Verilog)

- Will match existing expertise to design and simulation effort
- Each lab will contribute a subset of effort

LBNL:

1. Amplitude and phase control (working in Front End System (FES))
2. Resonance control (working in FES)
3. Feed Forward (working in FES, but needs improvement)
4. Cavity conditioning mode
5. System simulation and integration

LANL:

1. High Power Protect (ready for commissioning)
2. Klystron feedback loop
3. Algorithm verification on the bench, at JLab, and on DTL1
4. Setpoint curves
5. Adaptive feedforward
6. Arc and Quench detection
7. System simulation and integration

ORNL:

1. Real Time Data Link and Event Link receiver (in progress)
2. Code compliance and conversion
3. Epics integration
4. Local test stand development
5. System simulation and integration

1.7 MILESTONES

The critical milestones are tied to the commissioning dates of the Front End, DTL, CCL, and SCL Linac subsystems. These dates are explicitly spelled out in the Integrated Project Schedule (IPS), a controlled document that defines the overall SNS schedule [4]. The main dates are extracted from the IPS (IPS10 R304, dated May 1, 2002) and summarized in Table 2.

The plan presented in this document is consistent with these commissioning dates. The following lower level milestones have been integrated into the plan schedule, which is presented in Appendix B:

1. Complete the conceptual design of the final system. Nov 02
2. Demonstrate amplitude and phase control at JLab. Jan 03
3. Complete the detailed design of the final Field Control Module (FCM). Feb 03
4. Produce FCM prototype and demonstrate its performance in the lab. Mar-May 03
5. Test the final control board at JLab. May-Jun 03
6. Test the final control board during commissioning of DTL1. Jun-Jul 03
7. Revise the design of the final control board if necessary. Aug 03
8. Begin production of the final system. Sep 03

System Description	LLRF System Available at SNS Site	IPS Marker	Start Commissioning	Remarks
Front End / RFQ	June 14 → shifted to Oct 17 '02	FETE10	Oct 29 '02	Backup underway
DTL tank 1	Oct 30 '02	DTLINK2	May 22 '03	
DTL tanks 2-6	Apr 21 '03 end date	DTFB30	Dec 01 '03	
CCL module 1	Dec 31 '02	CCLFB90	May 17 '04	
CCL modules 2-4	Jul 30 '03 end date	CCL245		
SCL module 1	Apr 10 '03	LAN21	Oct 1 '04	Prototype test underway
SCL modules 2-23	Sep 01 '04 end date	LAN41		

Table 2. High Level Schedule and Expected Delivery Dates for LLRF Systems

1.8 STAFFING AND BUDGET FOR FY '03, '04, '05

The overall effort to develop, design and build the LLRF systems had an approved budget of $14.2M. Through September 2002, approximately $4.5M is either spent or committed. A detailed plan (budget and schedule) will be loaded into MPM as part of the Estimate to Complete that will begin in January 2003. At this point the LLRF team does not foresee the need to budget additional funds. A risk assessment will be performed with the help of the Advisory Board when the design has been determined.

1.9 DELIVERY SCHEDULE

A delivery schedule for the LLRF control system has been developed and can be found in tabular form in Appendix A. This schedule adheres to the IPS commissioning dates presented in Table 2. The delivery dates have been shifted to the future relative to the IPS, which calls for delivery far in advance of the commissioning dates.

1.10 PROJECT SCHEDULE

The overall subproject schedule for the LLRF control system contains very little float. The conceptual development of the LLRF system and the integration, as well as the preparation for production goes hand in hand. At this point the project team does not foresee the LLRF control system being on the critical path for RFQ or DTL commissioning. For more details see the schedule in Appendix B. A more detailed resource-loaded schedule will be developed over the next month.

1.11 BIBLIOGRAPHY

[1] Report from the Low Level RF Review Committee of the Spallation Neutron Source, Bob Siemann et al., September 2002.

[2] Low Level RF Control System Requirements for RFQ, Linac, and HEBT, SNS 104010300-SR0002-R00, October 2002.

[3] http://www.sns.gov/projectinfo/llrf/

[4] http://it.sns.ornl.gov/project_controls/IPS.htm

APPENDIX A. DELIVERY SCHEDULE

Dates in bold font are taken from the Integrated Project Schedule, IPS 10 R304, dated May 01, 2002. With the exception of RFQ and DTL1, the scheme for determining DTL and CCL delivery dates is to allow two months for conditioning and one month for installation, setup and checkout of the LLRF control system. The IPS specifies start and end dates for conditioning and commissioning of the SCL; the dates for these activities are equally distributed between these IPS boundaries. The delivery dates for the SCL are set for two months prior to conditioning. Note the SCL commissioning begins before SCL conditioning is finished; there is overlap during October 1-21, 2004.

RFQ	Deliver LLRF	Begin Conditioning	Begin Commissioning	
1	21-Oct-02	23-Oct-02	**29-Oct-02**	IPS Finish **31 Dec 02**

DTL Tank	Deliver LLRF	Begin Conditioning	Begin Commissioning	
1	22-Mar-03	22-Apr-03	**22-May-03**	
2	1-Sep-03	1-Oct-03	**1-Dec-03**	
3	1-Sep-03	1-Oct-03	**1-Dec-03**	
4	1-Sep-03	1-Oct-03	**1-Dec-03**	
5	1-Sep-03	1-Oct-03	**1-Dec-03**	
6	1-Sep-03	1-Oct-03	**1-Dec-03**	IPS Finish **01 Apr 04**

CCL Module	Deliver LLRF	Begin Conditioning	Begin Commissioning	
1	17-Feb-04	17-Mar-04	**17-May-04**	
2	17-Feb-04	17-Mar-04	**17-May-04**	
3	17-Feb-04	17-Mar-04	**17-May-04**	
4	17-Feb-04	17-Mar-04	**17-May-04**	IPS Finish **18 Aug 04**

SCL Cavity	Deliver LLRF	Begin Conditioning	Begin Commissioning
1	15-Feb-04	**15-Apr-04**	**1-Oct-04**
2	17-Feb-04	17-Apr-04	2-Oct-04
3	19-Feb-04	19-Apr-04	3-Oct-04
4	21-Feb-04	22-Apr-04	4-Oct-04
5	24-Feb-04	24-Apr-04	5-Oct-04
6	26-Feb-04	26-Apr-04	6-Oct-04
7	28-Feb-04	29-Apr-04	7-Oct-04
8	2-Mar-04	1-May-04	8-Oct-04
9	4-Mar-04	3-May-04	9-Oct-04
10	6-Mar-04	6-May-04	10-Oct-04
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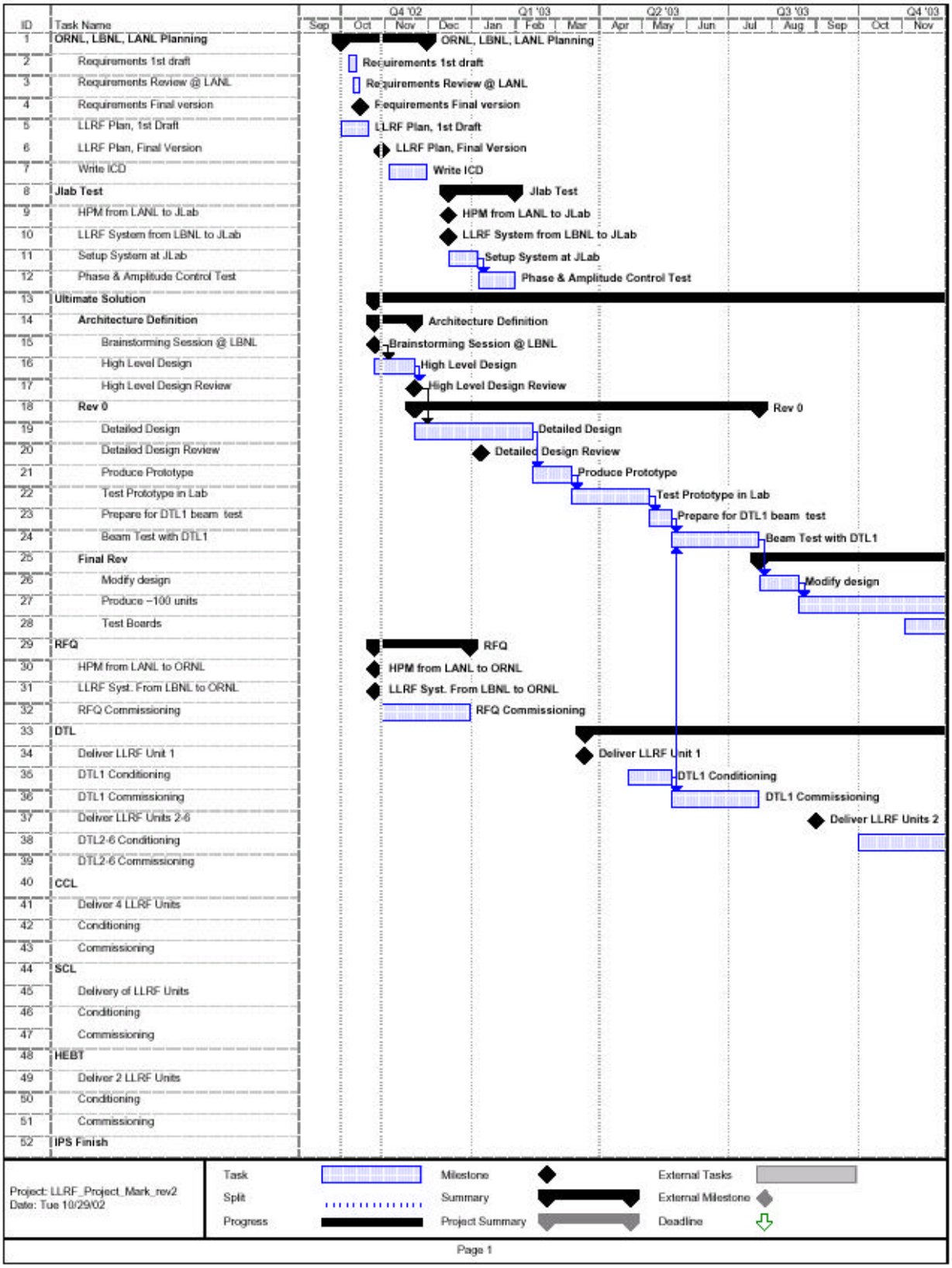
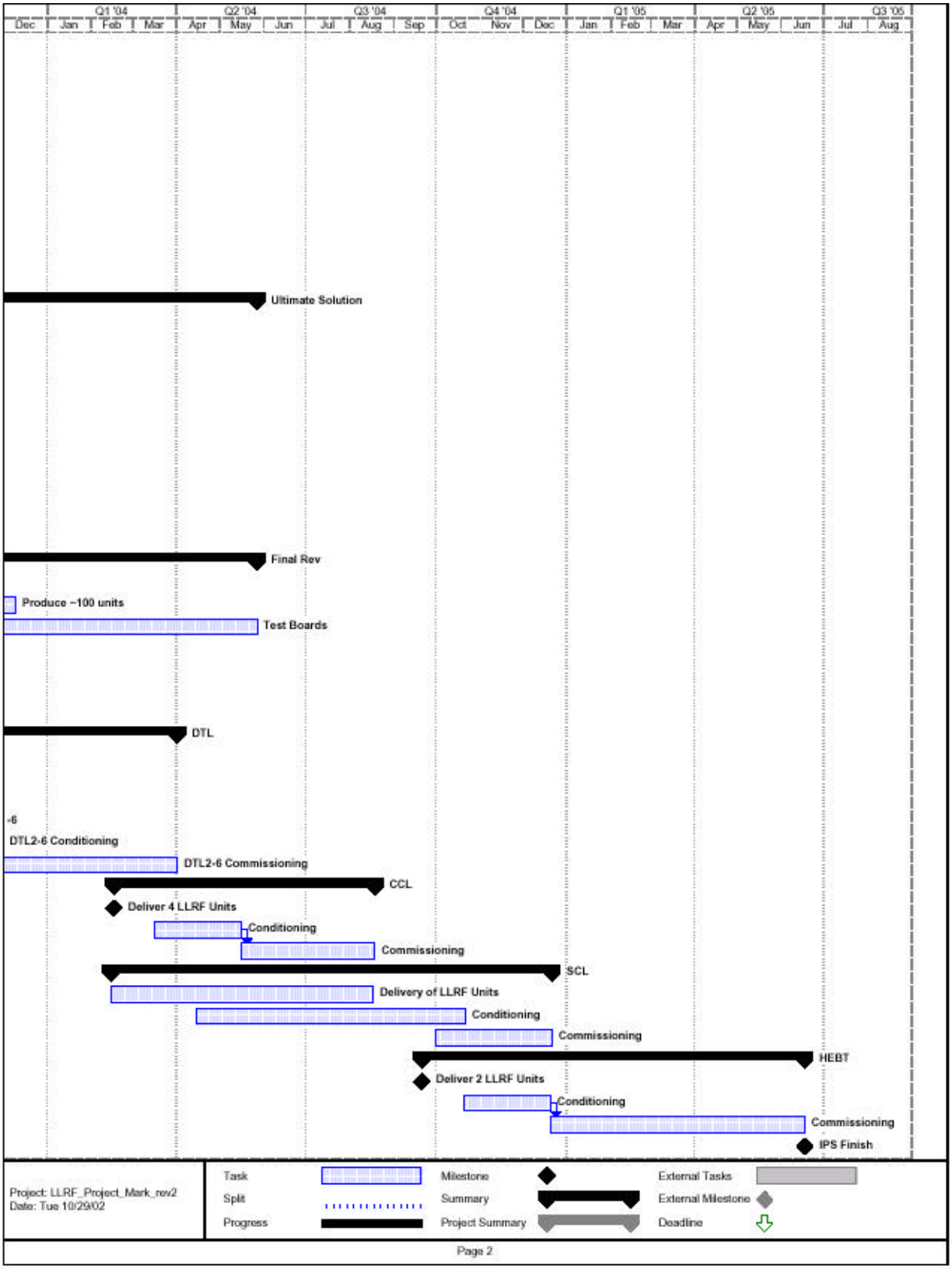
79	12-Aug-04	14-Oct-04	18-Dec-04	
80	14-Aug-04	16-Oct-04	19-Dec-04	
81	17-Aug-04	19-Oct-04	20-Dec-04	IPS Finish **21 Dec 04**

HEBT Cavity	**Deliver LLRF**	**Begin Conditioning**	**Begin Commissioning**	
1	21-Sep-04	21-Oct-04	**21-Dec-04**	
2	21-Sep-04	21-Oct-04	**21-Dec-04**	IPS Finish **17Jun 05**

APPENDIX B. PROJECT SCHEDULE

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